Applicability of the Three Omega Thermal Conductivity Measurement Method to Determining Thermal Conductivity Variations Normal to the Specimen Surface

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Many materials, such as CVD diamond, exhibit spatial variations of thermal conductivity normal to the specimen surface. Nonlinear theories of thermal wave propagation in such media have been developed yet they may be difficult to apply except perhaps to materials exhibiting uniform thermal conductivity gradients. We have employed a computer algorithm to calculate the signal expected from the three omega method based on approximating the specimen by a large number of uniform layers. The signal for a thermal conductivity profile, $\kappa(z)$, composed of the sum of a constant and exponential function, $\kappa(z) = A + B\exp(az)$, has been calculated, where z is the distance from the bottom (unheated) surface of the specimen. It can be shown that the linear profile is included in this set of profiles ($a = 0$). A nonlinear fitting routine was implemented for the purpose of obtaining thermal conductivity profiles from experimental data.

In order to test the model, we measured the three omega signal from a specimen of CVD diamond which is expected to show a large thermal conductivity variation through its thickness. A fit assuming the specimen had a uniform thermal conductivity was poor.

When the above equation was used to estimate the thermal conductivity profile in the specimen, we obtained several good fits to the data. However, a unique solution could not be found. Two layer solutions were nearly indistinguishable from 256 layer solutions. Furthermore, a good fit was highly insensitive to the value of a. Thus, additional independent information would be needed in order to identify the proper solution. It was found that a spatial average of each of the fitted profiles agreed reasonably well with the transverse thermal conductivity value obtained from other measurements made with a form of Ångström's method on the same specimen. In conclusion, the three omega method can indicate the presence of a spatial variation of thermal conductivity; however, the profile of this variation cannot be determined uniquely.

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